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VIGILANCE DECREMENT: A CRITICAL REVIEW OF THE LITERATURE AND AN EXPERIMENTAL PROGRAM

Paul Bakan

This paper presents a critical review of the literature related to the problem of vigilance. It ~~also~~ presents an outline for an experimental program, the purpose of which is to investigate some of the variables which influence vigilance or the maintenance of sustained attention. Attention may be regarded as a set or readiness to make a certain discrimination. Vigilance may be regarded as a form of sustained attention. It is in terms of vigilance or attention, as an intervening variable, that one would describe fluctuations or changes in the success with which ~~organisms~~ skilled in a particular discrimination make that discrimination over long-time periods of time.

While vigilance as defined above may be important in tasks involving periodically presented stimuli, tasks which involve aperiodicity are the ones that especially require the kind of sustained attention implied in the concept of vigilance. Such aperiodicity is met in a variety of life situations: in tasks performed by night lookouts, sentries, radar operators, sonar operators, proofreaders, and others. All of these individuals are required, over long periods of time, to watch or listen for events occurring at unpredictable intervals and sustained attention is important to their success on the job.

It has been shown that when attention is maintained over a period of time it usually undergoes a decrement or loss in efficiency (1, 5, 6, 7). Knowledge about the attention decrement is best extended by exploring the effect which certain variables have upon it. Some obvious variables to consider as possibly influencing the pattern of change in efficiency of attention over a period of time are the difficulty of the discriminations required, the monotony of the situation, the meaningfulness of the discriminatory task, the presence and distribution of rest periods, drugs, atmospheric conditions, motivational factors and the like. Some of these variables have already been

partially explored. Some are the subjects of investigations proposed in this paper.

The first systematic work on the decrement of sustained attention was undertaken during the last war when it became important to know more about the psychological factors involved in the detection of faint visual or auditory signals. Before the war, Wyatt and Langdon (10) had reported a pertinent study indicating a decrement of efficiency during a period of cartridge-case inspection. The inspection work was done in four-hour spells. Throughout any such period it was reasonable to assume that the truly defective cases would be randomly distributed, with an approximately equal number coming along in each fraction of the work period. It was found, however, that the average percentage of cases rejected by the inspectors (i.e. defects which were identified) varied from about four per cent down to one per cent. A marked decrease in the number of rejects occurred after the first 30 to 45 minutes of work; this decrease continued for about 90 minutes and was followed by an irregular recovery.

During the war, Lindsley and his associates (5) did a study to determine whether long and repeated periods of watching a radar scope resulted in loss of efficiency of performance. The ability to detect weak visual signals was taken as the measure of efficiency of performance. During the study, eight practiced subjects operated radar sets continuously for four hours per day without rest, six days a week for 17 days. For scoring purposes, each four-hour period of operation was divided into twelve 20-minute periods of signal presentation. A high rate of presentation was used, with 1116 signals given during every four-hour session. When the average number of missed signals was computed, it was found that there was a decrease in the number of stimuli detected in the second hour as compared to the first hour. This decrease with time was significant at the five per cent level. Target detection over the third and fourth hours was essentially the same as for the second. It is of interest to note, however, that the decrement here described did not appear until the third test day.

By far the most comprehensive work on vigilance is found in the wartime studies carried out by Mackworth (6, 7). Because these studies will be subsequently criticized they are outlined here in some detail.

Mackworth's Studies

The Experiments

Mackworth developed the Clock Test, a test intended to have qualities similar to those of a prolonged visual search. In this test, the subject is

required to watch a pointer as it moves in steps, like the second hand of a large clock in front of a plain white vertical surface. The pointer jerks on to a new position once every second, one hundred of these movements making the full circle. At irregular intervals, the pointer moves through double the usual distance, and whenever this occurs the subject is to report the event by pressing a response key.

In Mackworth's work the double movements occurred 12 times in the first half hour of the vigil. The second, third, and fourth half hours of the tests were continuous with the first and within each the time distribution of the double movements was identical with that of the first half hour. Immediately before the two-hour session began, the subject was given a five-minute practice period which consisted of a preliminary run on the first five double-length stimuli of the test series: i.e., the five-minute practice period was the same as the first five minutes of the test session in number and time distribution of stimuli. During the practice period the experimenter watched the clock with the subject. After the first one or two double length movements and before the subject pressed the key, the experimenter said, "Now" or "That's one." Also during this practice period the experimenter gave the subject complete knowledge of results by telling him when he was right and when he made mistakes in pressing the response key.

Results for the two-hour test period are given in terms of the mean percentage of missed signals in each half-hour. The figures representing the per cent of missed signals for the successive half hours were as follows: (a) 15.7, (b) 25.8, (c) 26.8, (d) 28.0. There was a progressive increase in the number of double movements missed as a function of time, with the difference between the first and second half hours being the most marked.

In his subsequent experiments, Mackworth modified this basic situation by introducing the following factors:

Rest period. A half hour of rest was interposed between the first half hour of watch and the second half hour of watch. Here, no significant drop was found in the number of signals detected during the second half hour as compared to the first.

Telephone message. The subject was given a telephone and told that he would receive messages during the test. Actually he received but one message. Under this condition, the number of signals missed before the message was received was greater than in the the original clock-test situation. When the message came, just before the beginning of the third half hour, telling the subject to try to do better, there was a marked reduction in the number of signals missed. The average level

of efficiency of the group for the third half hour was raised to a point characteristic of fresh subjects. This effect lasted for about a half hour.

Display board. An extra display board was introduced. An arrow crept slowly across the board and the subject was told to be especially on the alert when the arrow was passing through a "Danger Area," marked on the board, because more signals were to be expected during that part of the test. The arrow was timed to enter the "Danger Area" just before the third half hour and to leave it at the end of the third half hour. It was found that this technique had no effect on the efficiency of the subjects during the third half hour of the experiment or at any other time.

Knowledge of results. When the subject was given immediate knowledge of results for both correct responses and errors, it was found that there was a clear advantage in favor of the subjects who were supplied with knowledge of results, except for the first half hour when the subjects were fresh.

Benzedrine. When subjects were given benzedrine tablets one hour before the experimental session, they showed no decrement in efficiency over the two-hour experimental period. They were compared with a control group which took placebos, and did show a decrement.

Mackworth's Theoretical Interpretation

Mackworth (7) has analyzed his experimental situation and describes his results in terms of concepts from conditioning theory. The response of pressing the key when a double movement of the clock pointer appears is called a conditioned voluntary response. The command "Now" during the practice session is considered to be the unconditioned stimulus, since by itself it would have led to the original voluntary instructed response. The long movement of the clock hand is considered to be the conditioned stimulus. Knowledge of results, in the form of the comment, "Yes, that was right," during the practice period, is considered as reinforcement.

The response is called an instrumental conditioned response because the unconditioned stimulus leading to the original reaction is entirely different from the reinforcing stimulus which follows the conditioned response. The reinforcement is a form of derived or secondary reinforcement.

The hypothesis is then proposed that the decrement in vigilance is due to partial experimental extinction arising from the absence of the reinforcing

stimulus during the two-hour session. The presumed reason why only partial extinction took place was because "the principle of expectancy operating through self-instructions prevented the experimental extinction in the Clock Test from becoming complete and kept performance up to a partial extinction level" (7, p. 92).

Mackworth (7, p.87) considers two alternative explanations, one in terms of secondary extinction, the other in terms of conditioned inhibition. In the explanation in terms of secondary extinction it must be assumed that initially there exists a tendency for the conditioned voluntary response to be made to all movements of the clock hand including the short movements. During the practice period, response to the short movements is extinguished. Subsequently, conditioned responses to other similar stimuli may become spontaneously extinguished, the amount of this secondary extinction being a function of the similarity between the stimuli for the extinguished and the non-extinguished conditioned responses. In this explanation, then, the extinction of the response to the short stimulus is the condition which leads to the reduction in frequency of response to the long signal.

For the explanation in terms of conditioned inhibition, the assumption is made that the time interval between successive short signals is the critical stimulus. This stimulus acquires inhibitory properties through being so often associated with the differentially inhibited short signal. Since the long signal follows the identical time interval, once the inter-stimulus interval has acquired inhibitory properties, the bond between the long signal and the response could conceivably weaken because the long signal is paired with an inhibiting stimulus.

Mackworth (7, p. 89) has rejected both the secondary extinction hypothesis and the conditioned inhibition hypothesis, on the grounds that if these were in fact the mechanisms the vigilance decrement should not disappear when knowledge of results is given.

Critique of Mackworth

Mackworth's work is original, instructive and stimulating, but certain aspects of his interpretation of the results appear subject to criticism.

Practice period. It will be recalled that in Mackworth's studies, each experimental session was preceded by a practice session of five minutes. Immediately following this the test session commenced and in each half hour the double-length movements occurred 12 times at irregular intervals. The inter-stimulus intervals for the practice period were exactly the same

as the intervals for the first five stimuli in the series of 12 stimuli in the first and subsequent half-hours.

Mackworth has assumed that the half-hour sub-periods of the experimental session are comparable. It can be argued, however, that this assumption is not necessarily valid, since the practice period precedes only the first half hour and not the subsequent half hours. In the practice period, the subject gets complete knowledge of results about his performance. The subject may also infer that the task in the succeeding period will be similar to that of the practice period. Any temporal expectancy built up during these practice trials prepares the subject to respond to succeeding stimulus patterns similar to the practice pattern. Then the experimental session begins and the expectancy built up in practice is fully confirmed in the first five stimuli presented.

Such thinking, quite independent of an hypothesized decrement, would lead us to expect fewer omissions for the first five stimuli in the first half hour as compared with later stimuli. This is exactly what was found. For the first five signals in the first half hour there were 10.6% omissions, but for the next seven stimuli in the first half hour there were 19% omissions. This might be interpreted as evidence for the onset of decrement after only five minutes observation, but it might alternatively mean that a good part of the large (and significant) difference between the first half hour and the second half hour was due to an effect of specific temporal expectancies set up during the practice period. Over the second, third, and fourth half hours where these expectancies could not operate so effectively there was only a slight insignificant drop.

According to this reasoning, the extent of the decrement as reported by Mackworth might be changed considerably by the elimination of the confounding practice period. In the design of similar experiments, a practice period, if one is called for, should not be the same as any part of the experimental period, and should, if possible, be scheduled on a different day.

Rigidity in use of conditioning concepts. Another thing which may be criticized in Mackworth's reports is his apparent "forcing" of conditioning concepts in order to integrate the data. Mackworth himself seems to realize this when he says, "it would not be impossible to interpret the findings in another way in more general terms"; but he has used conditioning principles as a heuristic device to produce experimentally verifiable hypotheses. It is our feeling that this procedure also introduces rigidity in thinking about the problem and that this rigidity may be more detrimental than helpful.

The experimental situation has been set up in the following conditioning paradigm:

CS -- long movement of clock hand
US -- command "Now" (during practice)
CR -- press key
Reinforcement--knowledge of results (during practice)

It should be noted that on the basis of this paradigm the practice period is very important because in it are contained the unconditioned stimulus and the reinforcement necessary to establish the response. It is clear, however, that the response of pressing the key to a double-length stimulus could be set up without a practice period, without the command, "Now" and without reinforcement in the form of knowledge of results. This can be done simply by telling the subject what you want him to do. In other words, the elements of the laboratory conditioning situation are really superfluous in establishing the vigilance set.

Examples of the rigidity produced by Mackworth's theorizing are found in his interpretation of the effect of some of the experimental variables--in particular, his treatment of the telephone message, the pointer in the danger zone, and the test condition employing knowledge of results. His emphasis on conditioning concepts neglects possible motivational factors.

Disinhibition vs motivational factors. The marked reduction in missed signals following the telephone message is interpreted by Mackworth as disinhibition of the partially extinguished response of pressing the key in response to a double-length stimulus. This interpretation is based on the view that the telephone message is extraneous to the task. The explanation for the lack of disinhibition due to the display board pointer going through a "Danger Zone" is that the watching of the pointer on the board has become an integral part of the task.

But, in addition to the factors of suddenness and extraneousness, there were other differences between the telephone message and the display board situations. The telephone message told the subject to try to do better for the rest of the test. The implication of this message to the subject might have been that he was not doing as well as he should. There was no such implication in the display board pointer situation. Therefore, the telephone message may have had a special motivating effect which the display board did not have. Mackworth does not consider this when he reasons that the improvement resulting from the telephone message was not due to a sudden strengthening of the desire to please the experimenter. He argues that if this were an effect of motivation, then the display board experiment should logically have

given the same improvement. But the special motivating effect of the telephone message may have been greater than Mackworth believes.

Furthermore, the telephone message was conveyed by a human experimenter, a figure of authority, especially since the subjects were servicemen. In the display board situation, however, the message was conveyed by an impersonal pointer. This too would argue for the presence of differential motivation in these tests. It appears then that Mackworth may not have given sufficient weight to motivational factors in his account of his results. This much is certain, that in order to determine whether an extraneous stimulus has a disinhibitory effect, it will be necessary to use a stimulus which is not confounded with motivational factors. Perhaps a signal tone or light would be satisfactory in testing the disinhibition hypothesis.

Reinforcement confounded with special motivational factors. In the same way, we might consider that the effect of knowledge of results in preventing a decrement was due specifically to the fact that this knowledge came directly from the experimenter in his voice. Over a loudspeaker, the experimenter called, "Yes, that was right," "No, that was wrong," and "You missed one there." It is possible that the subject's awareness of the experimenter's direct knowledge of his performance resulted in a greater desire to please the experimenter. A more automatic, or objective signaling of knowledge of results would eliminate this confounding factor.

Mackworth's alternative hypotheses. The two alternative hypotheses which Mackworth considers, but rejects, both imply a spread or transfer of inhibition or extinction. His second hypothesis of conditioned inhibition based on the time interval between successive stimuli is clearly too specific to his situation to be of general utility. Most vigilance situations do not have events occuring regularly at some regular, paced rate. The one-per-second sequence of pointer movements, if used in the explanation of the vigilance decrement, shapes the explanation in such a way that it does not apply to normal radar scope observation or lookout observation.

Mackworth's rejection of his alternative hypotheses because of the effect of knowledge of results does not seem necessary. Mackworth expects knowledge of results to influence experimental extinction only, but we see no reason why it might not also forestall secondary extinction or conditioned inhibition. Hence if one presses for a conditioning description of the vigilance decrement, it might be possible to conceive of one in terms other than those which Mackworth has adopted. Whether or not this course is followed depends on how profitable one feels a conditioning description of this behavior is.

Possibility of a discrimination orientation. Whereas, conditioning interpretations of these Clock-Test studies draw specific attention to the key-pressing response, it may be more profitable in seeking a general description of vigilance decrement to think of the total behavior picture, including the sensory discrimination, the decision to press the key or not press it, and the actual motor response. When the vigilance task is conceived as basically a discrimination task, one is led to inquire about threshold changes during the watch period, or to study the variation in decrement as a function of the level of difficulty of the required discrimination.

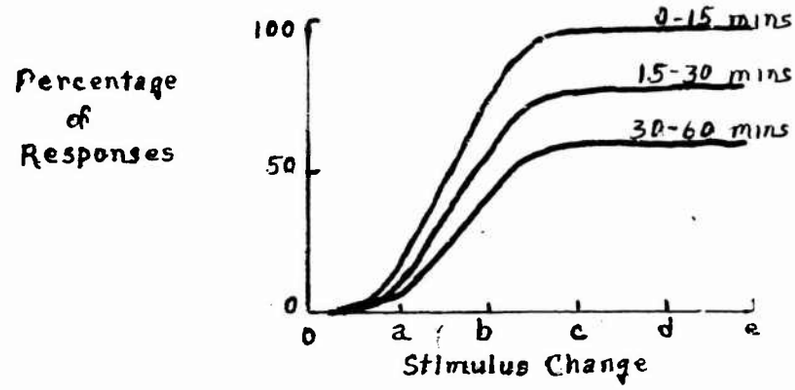
Effect of Discrimination Difficulty on Attention Decrement Some Hypothetical Curves

In the discussion that follows, we shall examine the hypothesis that the ability to discriminate, considered in a broad sense, declines during work at a task requiring prolonged attention. In situations which call for a simple sensory discrimination, such a decline means a progressive increase in any appropriate measure of the differential threshold. It is, therefore, instructive to speculate as to the manner in which the threshold or psychometric function changes during vigilance decrement. Various possibilities exist as to the nature of the change, some of which are shown in Figures 1, 2, and 3.

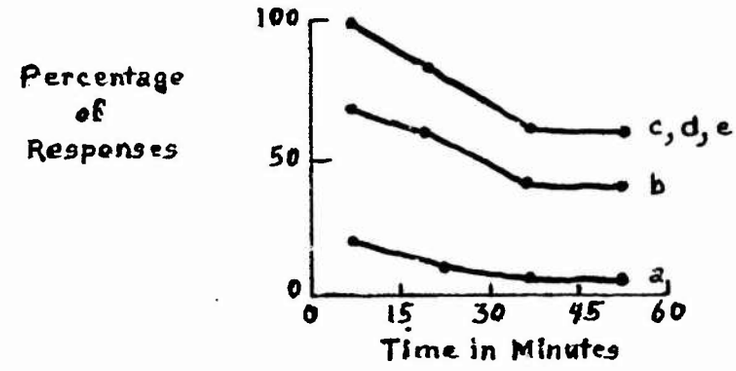
Consider first the parts of these figures that are identified as 1A, 2A, and 3A. In each there are three curves. One (marked 0-15 minutes) shows an assumed relationship between stimulus "strength," i.e. size, brightness, etc., and the likelihood of response during the early part of the watch period when the subject is vigilant. The other curves describe possible forms of the same relationship at later times in the watch period when the subject is less vigilant. Each figure represents a different hypothesis as to the nature of the change in the subject's psychometric function which lies behind the decrement.

In Figure 1, the hypothesis represented is that the decrement is independent of intensity, i.e., has an equivalent proportionate effect on all responses regardless of initial probability of response. In other words, this hypothesis states that the decrement is simply a lowered likelihood of responding at all stimulus levels. All response probabilities are depressed by a given factor. As a consequence, if the threshold is defined in terms of some given percentage level of responding (say the 50% level) it increases during the watch period. A consequence of this hypothesis is that the decrement should appear just as early for stimuli of one intensity as for stimuli of another--that original stimulus detectability is not a factor in determining the onset of the decrement (see graphs in Figure 1B). This is contrary to common

A. Hypothesized change in psychometric function for detecting changes (i.e. for "brighter" judgments).



B. Decrement curves derived from curves in A above: Percent response as a function of time for different values of stimulus change.



C. Corresponding change in psychometric function for "equal" judgments.

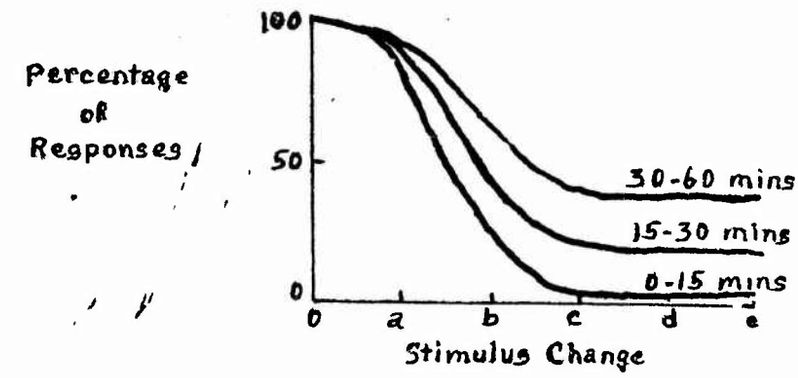
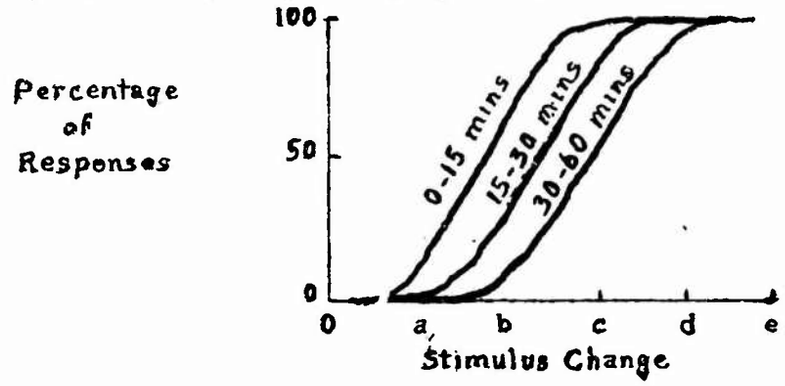
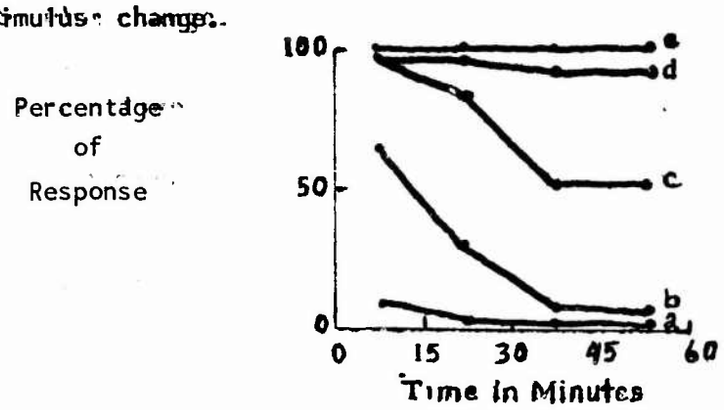


Figure 1. Relationships between discrimination difficulty, time, and percentage of responses generated by an hypothesis that decrement has an equivalent proportionate effect on the probability of all responses regardless of their initial probabilities.

A. Hypothesized change in psychometric function for detecting changes (i.e. for "brighter" judgments).



B. Decrement curves derived from curves in A above: Percent response as a function of time for different values of stimulus change.



C. Corresponding change in psychometric function for "equal" judgments.

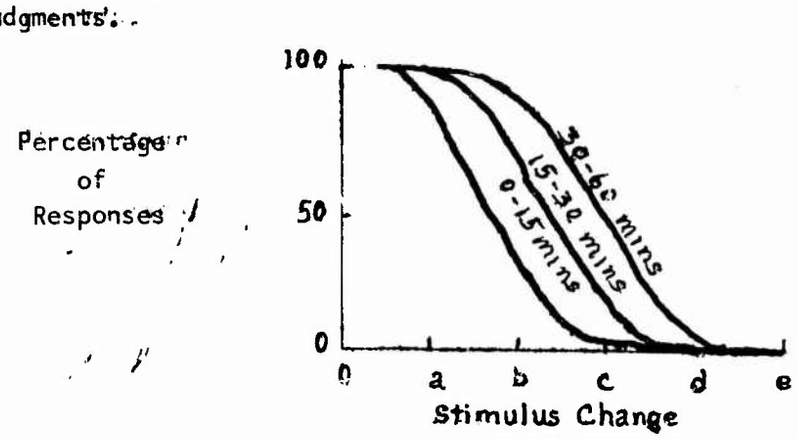
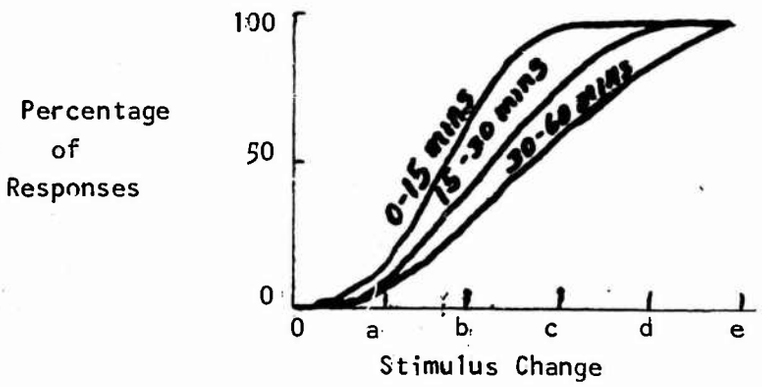
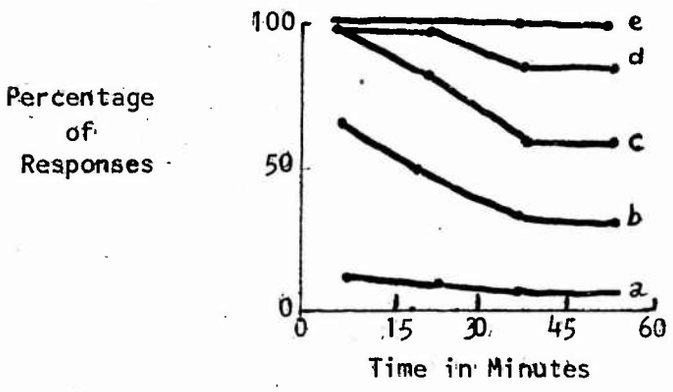


Figure 2. Relationship between discrimination difficulty, time and percentage of responses, generated by an hypothesis that as more time is spent in the vigillance task, the psychometric curve shifts up the stimulus scale, with no change in the slope of the function.

A. Hypothesized change in psychometric function for detecting changes (i.e. for "brighter" judgments).



B. Decrement curves derived from curves in A above: Percent response as a function of time for different values of stimulus change.



C. Corresponding change in psychometric function for "equal" judgments.

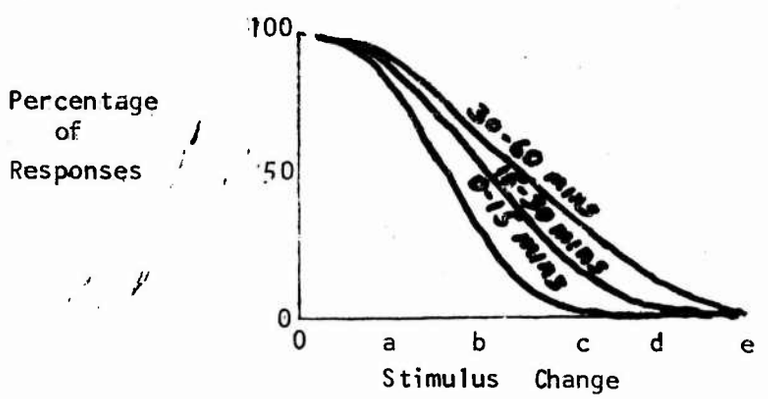


Figure 3. Relationship between discrimination difficulty, time and percentage of responses generated by an hypothesis that as more time is spent in the vigilance task, there is an increase in the stimulus range over which the psychometric function extends.

sense (e.g., we would not expect any decrement for the sound of pistol shots at close range) and to experimental evidence already provided by Fraser, Mackworth and others.

Fraser (3) used a form of the clock test in which it was easier to detect double movements. All pointer movements were four times as large as in the original clock test. Under these conditions there was no significant decrease in the number of movements detected in the second half hour, when compared with the first. Unfortunately the experimental sessions were not carried beyond one hour, but we do know from these data that if a decrement does occur in this situation its onset is later than in the original test situation.

Mackworth's data (7) come from his tests in a simulated radar situation. Two levels of stimulus brightness were used. The absolute level of detection efficiency was found to be a function of the brightness level of the stimulus: there were more detections for the brighter one. Also, the decline of performance with time was less steep with the bright stimulus than with the dim one. Therefore, the appearance of a statistically reliable decline in accuracy of detection was delayed for the brighter stimuli as compared with the less bright.

Two other experiments have produced results in the same vein. In the study by Lindsley (5) where the size of the pip to be detected was a variable, a difference was observed between a large pip and a small pip with respect to the time at which impairment occurred. Although it was not statistically significant, it was in the direction of earlier impairment for the small pip. In an experiment by Bills (2), subjects were required to name colors as rapidly as they could for ten minutes. One condition involved two colors on a color board, another three, another five. Although the decrement was not great for any condition, the amount of decrement was directly related to the number of colors. Naming two colors produced less decrement than naming five colors. If we assume that discrimination cannot be made as easily among five colors as between two, then these results are consistent with the hypothesis that with greater discrimination difficulty there is a more rapid decrement in performance.

On the basis of the composite of these data, then, the hypothesis depicted in Figure 1 is quite adequately ruled out as descriptive of the change in threshold behavior during vigilance decrement. Alternative hypotheses are illustrated in Figures 2 and 3.

Figure 2 represents the hypothesis that as the subject spends more time in the vigilance test, his psychometric curve shifts up the stimulus scale. It assumes essentially no change in the slope of the function.

of 1030 cps or 970 cps. After two hours the range of non-discrimination expanded to 60 cps. so that a note of 1000 cps could only just be distinguished from one of 1060 cps or 940 cps.

Clearly the results of both of these studies could be described by the changes depicted either in Figure 2 or Figure 3. Hence the interest of the present research program in examining more closely the nature of the change in sensory threshold which occurs with decrement. Although the foregoing discussion has been phrased in terms referring to simply sensory discrimination, we propose to explore the more general question of the effect of discrimination difficulty upon vigilance.

Figure 3 represents the hypothesis that the vigilance decrement is associated with an increase in the stimulus range over which the psychometric function extends. The hypotheses expressed in Figures 2 and 3 both imply an increased threshold after decrement and both allow for the fact that very striking stimuli may be associated with no decrement. (See 2B and 3B.) Both hypotheses mean, in substance, that the range of stimuli which will be accepted as equivalent to the background or neutral stimuli increases during a watch period. (See the section C of Figures 2 and 3.) But the mode of this increase is different in the two cases. Figure 2 implies the development of a broader "zone of indifference" or "zone of equality" with discriminations beyond this zone still reasonably sharp. Figure 3 implies a less sharply defined "equals" category after decrement. A combination of hypotheses 2 and 3 is, of course, possible although it has not been diagrammed here.

Relevant Experiments

Past research does not offer clear supporting evidence for either of these views as against the other. Bartlett (1), in a study of fatigue in highly skilled work, has observed "that standards accepted and followed by the central nervous system unwittingly deteriorate with increasing fatigue." Part of his experiment required the subject to move a control in response to movement of a pointer. At the beginning of the experimental session, the operator allowed the pointer to move only two or three degrees on either side of the vertical and then began at once to make the necessary control reaction. A little later he was letting it move five degrees either way, then ten degrees, and finally it could swing from side to side over a wide range before he made any corrective response. Thus Bartlett described fatigue as marked by a progressive lowering of standards set by "central" control, which control has functionally, but without knowledge of the subject, expanded the limits of its "indifference range." This means that in a state of fatigue there would be no decrement so long as the stimulus intensity is outside this progressively increasing indifference range. In other words, the onset and extent of measured vigilance decrements should depend on the stimulus change to be detected.

Experiments by Solandt and Partridge (9) on a problem of auditory vigilance offer preliminary confirmation of this thesis. They found that about two-thirds of their subjects showed a change in ability to make pitch discrimination during a long period of auditory attention. Each subject listened continuously to auditory signals for one and one-half or two hours. Every ten minutes his ability in pitch discrimination was tested. The average result was that certain men who when fresh to the task could distinguish a note of 1000 cycles per second (cps) from one of either 1015 cps or 985 cps, could after half an hour or more at the work only distinguish a note of 1000 cps from one

of 1030 cps or 970 cps. After two hours the range of non-discrimination expanded to 60 cps. so that a note of 1000 cps could only just be distinguished from one of 1060 cps or 940 cps.

Clearly the results of both of these studies could be described by the changes depicted either in Figure 2 or Figure 3. Hence the interest of the present research program in examining more closely the nature of the change in sensory threshold which occurs with decrement. Although the foregoing discussion has been phrased in terms referring to simply sensory discrimination, we propose to explore the more general question of the effect of discrimination difficulty upon vigilance.

Proposed Experimental Tests of Vigilance as a Function of Discrimination Difficulty

Discrimination difficulty will be studied with respect to two different types of stimulus material, which we may call "sensory" material and "symbolic" material.

Experimental Materials: Sensory

The apparatus for the study of decrement with sensory material will require a brightness discrimination. It consists of a generally illuminated white panel within which the subject sees four small circles of light. These four lights can be made to flash on and off every second, staying on for two-thirds of a second and off for one-third of a second. The experimenter can, at any time, make one of these four lights flash brighter than the other three. The subject signals his detection of such a flash by pressing the appropriate one of four response switches. The brightness difference between the brighter light and the other three lights can be varied by the experimenter. In this way the discrimination difficulty may be varied.[1]

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[1]The apparatus is described in more detail in Memorandum Report B-4. Briefly, it is built to make possible the following variety of experimental arrangements:

a. Four lights flashing on once per second, with one (or more) of four aperiodically brighter (scheduling by experimenter).

b. Same as (a) except that lights do not go totally out between flashes.

c. Four lights on all the time, with one (or more) of four aperiodically flashing brighter for 2/3 second.

d. Stimulus field reduced by using one, two, or three lights instead of four.

e. Stimulus field modified by changing size and separation of light patches.

f. Aperiodic signals modified to consist of two consecutive flashes instead of one.

Preliminary experiments are being carried out with these arrangements to find an optimal testing situation.

The efficiency of the subject's performance at any level of discrimination difficulty can be measured by the number of errors. Errors of omission are probably most important. Such an error occurs when the subject fails to make a response to a brighter flash. Errors of commission occur when the subject makes a response to what he sees as a brighter light, when, in fact, one of the lights did not get brighter. Mackworth (7) mentioned such errors, but did not analyze them. Errors of place may occur when the subject responds at an appropriate time, but presses the wrong switch.

Experimental Materials: Symbolic

For the study of attention decrement in a "symbolic" activity, a listening situation has been devised in which the subject attends to a series of digits which have been recorded, one digit per second, on a magnetic tape. The subject is given a "set" to listen, for example, for sequences of three consecutive odd numbers. Whenever he hears such a sequence he is to write it on a card. These three-odd-number sequences occur at irregular times in the tape recording and the subject must maintain the set to discriminate these sequences from any other arrangements of numbers.

There will be four forms of this test. In each form, the discrimination that determines the making or not-making of a response will be of a presumed different order of difficulty. The following four types of sets or instructions, presented in presumed order of difficulty, will be used for the different forms:

1. Respond only to sequences of three identical numbers.
2. Respond only to sequences of three different consecutive odd numbers.
3. Respond only to sequences of three different consecutive numbers in the order: odd--even--odd.
4. Respond only to sequences of three consecutive numbers in the order even--odd--even, when they are arranged in either ascending or descending order.

It is possible that the vigilance task with these verbal materials can be used effectively as a group test, inasmuch as there is no limit to the number of subjects who can listen simultaneously to the tape recording. The only requirement is that subjects be sufficiently well isolated from each other that their responses are independent. When the test characteristics are better known, it may be of interest to investigate its validity as a selection instrument for personnel who are required to maintain attention over long periods of time.

Experimental Design

Testing sessions for both types of experimental situations will last one and one-half hours. Within this period there will be six 15-minute sub-periods equated with respect to number and distribution of stimuli to be responded to.

Stimuli (light flashes or digits) will be presented regularly every second. The stimuli to be responded to will occur at irregular intervals, determined randomly in advance. The place of appearance of stimuli to be responded to will be the same in each sub-period to allow for comparison of errors in the different sub-periods.

Preliminary experimentation will be devoted to a determination of the effects of practice on the vigilance task. Depending on the outcome of these tests, an experimental design will be set up involving either (a) random groups, each working several days at the same task, or (b) random groups, each working through tasks of all difficulties in accordance with a Latin Square arrangement.

Independent groups of subjects will probably be used for the brightness situations and the number situation.

The number of errors for each sub-period will be plotted for the different difficulty levels. For the brightness data, additional plots will be made showing change in the threshold curve as a function of time.

Other Experimental Suggestions for the Study of Vigilance Behavior [32]

Tests with Mixed Difficulty Tasks

The designs described above require that on any one day a given subject is tested at only one difficulty level. However, in practical situations it is often necessary for workers to respond to stimuli of mixed difficulty in the performance of a task. For example, a radar operator must respond to stimuli of mixed-difficulty in the performance of a task. For example, a radar operator must respond to both large and small signals, dim and bright signals, etc. This raises (a) the question of how the vigilance decrement is affected by a stimulus presentation schedule involving stimuli of varying discrimination difficulty, and (b) the question of how the decrement proceeds for each of the stimulus levels separately.

One hypothesis might be that the presence of stimuli requiring easy discrimination would impair the detection of stimuli requiring more difficult discriminations. This implies that a set to make both easy and difficult

discriminations is less efficient for making difficult discriminations than a set to make only difficult discriminations. On the other hand, the presence of stimuli requiring discriminations of mixed difficulty may serve to reduce the monotony of the situation. If we postulate that less monotony makes for less decrement in a vigilance task, then we might predict more stimulus detections for all levels in the mixed difficulty situation. A similar prediction derives from the interpretation that the easier stimuli would provide the subject with more self-reinforced trials, and would serve to keep him "awake" and hence to maintain the set.

In view of these considerations, an experiment will be arranged in which stimuli requiring discriminations of different difficulty will be presented within the same test period. The brightness situation will be the more suitable for this experiment. Subjects will be instructed to respond to any flash which is brighter than the background flashes. But the brightness of those brighter flashes will vary on different tricks. Curves showing the decrement can then be plotted for overall performance and for performance on the stimuli of different difficulty levels.

Effect of Subject's Conception of His Performance Efficiency

In most of the situations described above, the subject has no way of knowing how well he is performing in his task. Thus it is possible for the experimenter to give the subject any kind of information regarding his efficiency, in an attempt to evaluate the effect of this information on the subject's efficiency.

For an experiment in this area, a special signal light would be used. There might be three groups of subjects. Those in Group 1 would be told, "The light will go on when you are not working efficiently." Although the light would, in fact, go on after decrement, it would go on at a pre-established time for all subjects of the group.

Subjects in a second group would also be told, "The light will go on when you are not performing efficiently." But for these subjects, the light will never go on. They, therefore, may infer that they are performing efficiently.

A third group would be told nothing about the meaning of the signal light. But the light would go on at the same time as the light for Group 1. These subjects would not know whether they are performing efficiently or inefficiently.

If performance in a vigilance task is influenced by the subject's conception of how well he is doing, the foregoing groups would be expected to arrange

themselves with group 1 best and group 2 poorest.

Mackworth was criticized earlier as not having satisfactory data on which to base conclusions regarding the function of extraneous stimuli because he had confounded a motivational variable (the contents of the telephone message) with an extraneous stimulus variable (the occurrence of a telephone message). In the experiment here proposed we may evaluate the difference in effect between a mere extraneous stimulus (the meaningless light for Group 3) and an extraneous stimulus which conveys a message with motivating value (the light for Group 1). If the meaningless extraneous stimulus produces improved performance, Mackworth's disinhibition hypothesis would not be upheld.

Other experiments may be performed to study the effect of "real" knowledge of results on vigilance efficiency. Mackworth has shown that knowledge of results prevents a decrement in performance. We would like to get more information on the effectiveness of different ways of presenting knowledge of results. We would also want to study the effect of different amounts of knowledge of results.

Additional Variables

There are other problems which might profitably be investigated in the area of vigilance behavior:

1. Relation of visual and auditory vigilance efficiency in the same subject.

2. The effect of the use of multiple observers on vigilance efficiency.

3. The effect of the presence of multiple observers on individual vigilance efficiency.

4. The effect of interspersed rest intervals on vigilance efficiency; length and distribution of intervals; type of activity during rest intervals.

5. Effect of meaningfulness of task on vigilance efficiency.

6. Effect of use of simultaneous visual and auditory stimuli on vigilance efficiency.

7. Relationship between a subject's initial ability in maintaining attention and his rate of decrement with time.

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